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BRIEFING BY THE ASTRONAUTS OF SHUTTLE MISSION 51–A

HEARING

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

NINETY-NINTH CONGRESS

FIRST SESSION

ON

BRIEFING BY THE ASTRONAUTS OF SHUTTLE MISSION 51-A

JANUARY 28, 1985

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BRIEFING BY THE ASTRONAUTS OF SHUTTLE MISSION 51-A

MONDAY, JANUARY 28, 1985

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
Washington, D. C.

The subcommittee met, pursuant to notice, at 10:05 a.m., in room SR-253, Russell Senate Office Building, Hon. Slade Gorton (chairman of the subcommittee) presiding

Staff members assigned to this hearing: Pete Perkins, professional staff member and Marty Kress, minority professional staff member.

OPENING STATEMENT BY SENATOR GORTON

Senator GORTON. Good morning. As chairman of the Subcommittee on Science, Technology, and Space I am delighted to welcome the astronauts from Space Shuttle Mission 51-A, NASA's 14th Shuttle mission.

I cannot make this statement without noting the fact that this is the first meeting of the Commerce Committee or of any of its subcommittees in the 99th Congress, and the Chairman of the whole committee is here, not chairing the very first meeting, and he is in the place which he has occupied for the last 2 years. I appreciate his permitting me to take the spotlight at this first meeting.

Each of you has given us the opportunity to experience pride in NASA and its accomplishments once again. Your historic mission exemplified the importance of teamwork and hard work. And, as much risk as there was in the two satellite recovery operations, most people in the United States, I believe, knew you could do it, as NASA has so many times in the past.

As Shuttle missions become more frequent, there may be a tendency for some people to overlook or to take for granted NASA's Shuttle achievements; rest assured, however, that the whole world marveled at the precision with which you securely retrieved and returned to Earth two faltering satellites—the first such maneuver since man began exploring the frontiers of space. Your achievements were the essence of pioneering heroics and will not soon be forgotten.

Like your colleagues on the Solar Max Repair Shuttle mission, your overcame adversity in mid-operation to achieve your ultimate objective. Moreover, that you were able to successfully secure the Palapa satellite

by manually berthing it after your initial attempt was frustrated is conclusive testimony to the true value of the manned presence in space.

Your skillful and resourceful recovery of the two satellites has ushered in a new era of space activity—one which predicts tremendous potential benefits for satellite owners and for each of us as the ultimate consumer. Furthermore, your ability to flawlessly execute this mission on such short notice highlights your success in salvaging what once was a seemingly hopeless situation involving the two wayward satellites.

Years from now, satellite recoveries will likley occur on a more routine basis, along with many other space activities that now fascinate and inspire each of us. Your accomplishments, however, were anything but routine; to the contrary, they were unprecedented. You will go down in hisotry as true pioneers who extended the envelope in terms of our abilities to live and work in space. Your efforts are a source of pride to all Americans, and for this we express our deepest gratitude.

I also would like to introduce to you and to everyone here Howard Cannon, who for many years was the distinguished Chairman of this Committee and who has joined us here this morning.

Senator Danforth, do you have any statements?

The CHAIRMAN. I do not, Mr. Chairman, thank you very much. I am delighted to be here and honored to be in the presence of such outstanding pioneers.

Senator GORTON. Senator Cannon?

STATEMENT OF HOWARD CANNON, FORMER U.S. SENATOR

Mr. CANNON. Thank you, Mr. Chairman—just to say that I was on the Space Committee when it was first formed in 1959, and some of the stories that we were told then about the possibility of putting stationery orbits out in space, about putting a man on the Moon eventually, and this sort of thing, just sounded like Buck Rogers.

Now it is an everyday event. When you can go up and recover a satellite in space, a disabled satellite, and bring it back and repair it and put it to use again, I think it has just been a tremendous development over those years, and I certainly want to join you in congratulating these folks here for an excellent job.

Senator GORTON. Thank you. Without objection, we have opening statements from Senators Hollings and Heflin which will be included in the record at this point.

[The statements follow:]

OPENING STATEMENT BY SENATOR HOLLINGS

Mr. Chairman, once again, the Members of this Committee are assembled to hear about the exploits of yet another space shuttle crew who have made a difficult mission look easy.

Thanks to the successes of the Nation's space program—and particularly the efforts of astronauts Hauck, Walker, Fisher, Allen, and Gardner--we are redefining the meaning of the three-R's. In the space age, the three-R's are Repair, Refueling, and Retrieval.

Last year, Members of this Committee listened with wondrous amazement as members of the Solar Max shuttle mission recounted their adventures as satellite repairmen. As Senator Heflin noted at the time, the script read like some kind of Grade B thriller: spacemen blast off to save a dying satellite, a daring Buck Rogers rescue attempt fails, and with time running out and fuel running low a human-guided robot arm plucks the satellite to safety.

We might not have pondered anything more incredible at the time, but it appears that the astronauts of Mission 51-A have done just about everything to top it. An astonished Nation watched as astronaut Joe Allen, strapped into his jet-powered backpack, rode easily into position beside the errant Palapa-B2 satellite. Gently maneuvering himself into position, he links himself to the spinning satellite and, upon firing his thrusters, slows the device to a halt. "Stop the clock!" exalted Allen. "I've got it tied."

Mr. Chairman, what was science fiction less than a decade ago is now scientific fact. Our nation's space program continues to evolve at an incredible clip—and of course we have NASA to thank for much of that.

Mr. Chairman, last year, when the payload assist modules (PAMs) failed to put the Palapa-B2 and Westar VI satellites into geosynchronous orbit, there was a great deal of concern about the ability of the shuttle to launch communications satellites. Less than 9 months later, the NASA team had put together a retrieval mission, Flight 51-A, and had resolved a myriad of legal questions. In addition, NASA had put together an impressive investigative team to assess the failure of the PAM's and appears to have resolved that problem as well. The Nation's space program is growing up, and we can all be proud of this offspring. I might also note that each shuttle mission further evidences the value of man/woman to the space program and the ability of man/woman to adapt to adverse conditions.

As noted in the Time magazine account of Mission 51-A,

"Yet for all the preparations, blueprints and complex hardware, it was finally the human in the loop that made the difference, the man in the bulky space suit who improvised when perfect schemes fell through; without the astronauts, the twin satellites might still be drifting in darkness, orphans of the cosmos."

Mr. Chairman, it is a pleasure to have the crew of Flight 51-A here today and to have an opportunity to hear of their exploits. In particular, I look forward to "Mighty Joe Allen's account of this mission. As the former Associate Administrator of NASA for Legislative Affairs, Mr. Allen won the respect and admiration of the Members of this Committee. I am pleased to see that he continues to be such a stellar performer.

In the past, the Members of this Committee have had the opportunity to salute several of the shuttle crews. However, I would be remiss today if I did not join the crew of Flight 51-A and salute the members of the NASA support team, in particular Flight Director Larry Bourgeois. Without the development of an exceptional contingency plan by the ground team, Palapa-B2 and Westar might still be in an unusable lower-earth orbit.

Mr. Chairman, I look forward to today's presentation and would like to personally congratulate each and every member of the crew of Mission 51-A for a job well done.

Opening Statement By Senator Heflin

Mr. Chairman, 1992 will mark the 500th anniversary of the discovery of America by Christopher Columbus. Thanks to the efforts of the crew of shuttle flight 51-A, this Nation is another step closer towards the establishment of a permanently manned presence in space by that date.

To paraphrase President Reagan's greeting to the crew upon the completion of their mission, "the Nation is proud of what you have done!"

Mr. Chairman, during the 8 days that astronauts Hauck, Walker, Fisher, Allen, and Gardner were in space, they managed to deploy two communications satellites—Anik D2 and LEASAT 1; they managed to conduct the first in a series of more than 70 organic and polymer science experiments that 3M Company hopes to conduct in space over the next decade; they continued experiments to monitor radiation exposure; and they managed to retrieve two errant satellites—Palapa B-2 and Westar—that were unsuccessfully deployed in February 1984 during shuttle mission 41-B.

Mr. Chairman, the significance of this mission is immeasurable, and it represents another step towards the eventual permanent presence of the U.S. in space.

I should note that the insurance industry that underwrote the recovery of Palapa B-2 and Westar VI was jubilant with the results of Mission 51-A. The management of Lloyd's of London ordered the famed "Lutine"bell rung twice, the insurer's traditional signal of a successful salvage, and the underwriters awarded astronauts Allen and Gardner the silver medal of merit for services rendered—only three other medals have been awarded since World War II.

Mr. Chairman, the National Aeronautics and Space Administration, the insurance representatives and the NASA contractors should be complimented for the yeomen's job they did in putting this mission together in less than 9 months. Quite frankly, the failure of the two payload assist modules (PAMs) last February seemed to spell disaster for NASA's shuttle manifest. But the Can Do Agency did it again, and now there are two satellites being refurbished that hopefully will soon be orbiting the Earth in geosynchronous orbit. NASA also has remedied the problem concerning the PAMs. The future shuttle manifest now appears to be secure, and the shuttle's future appears very bright.

Mr. Chairman, I know that I speak for all of the Members when I say that last May this Committee was dazzled by the exploits of the Ace Satellite Repair Company and the Solar Max Mission. Mission 51-A now has added a Towing Service which truly makes the shuttle system the most complete space transportation system known to man.

Mr. Chairman, I look forward to today's presentation, and I would like to compliment the men and woman of shuttle flight 51-A for a job well done. The dramatic capture of the Palapa and Westar communications satellites demonstrates beyond a doubt the unique capabilities of the shuttle and of man. I look forward to the astronauts' accounting of their mission, and I look forward to the completion of a permanently manned U.S. space station in 1992.

Senator GORTON. With that, Captain Hauck, we are going to turn it over to you.

STATEMENTS OF CAPT. FREDERICK "RICK" HAUCK, USN, COMMANDER, MISSION 51-A; CAPT. DAVID WALKER, USN, PILOT; ANNA FISHER, M.D.; COMDR. DALE GARDNER, USN; AND JOSEPH ALLEN, Ph.D., MISSION SPECIALISTS

Captain HAUCK. Thank you, Senator Gorton, Senator Danforth, Senator Cannon. It is a pleasure for us to be here. I would like to start out, if I could, by introducing my crew to you and the assembled audience.

On my right is Capt. Dave Walker, U.S. Navy, who was my co-pilot on the mission, and during the movie and slides that you will see later I need to point out that Dave was inside the Space Shuttle during the recovery effort and was orchestrating all of the efforts that Dale and Joe and Anna and I were doing during that part of the mission.

Dr. Anna Fisher was in charge of operating the remote manipulator arm during this operation. She was also my co-worker in completing all of the rendezvous maneuvers that we did to rendezvous with the two satellites. She also conducted the 3M experiment, DMOS, Diffusive Mixing of Organic Solutions.

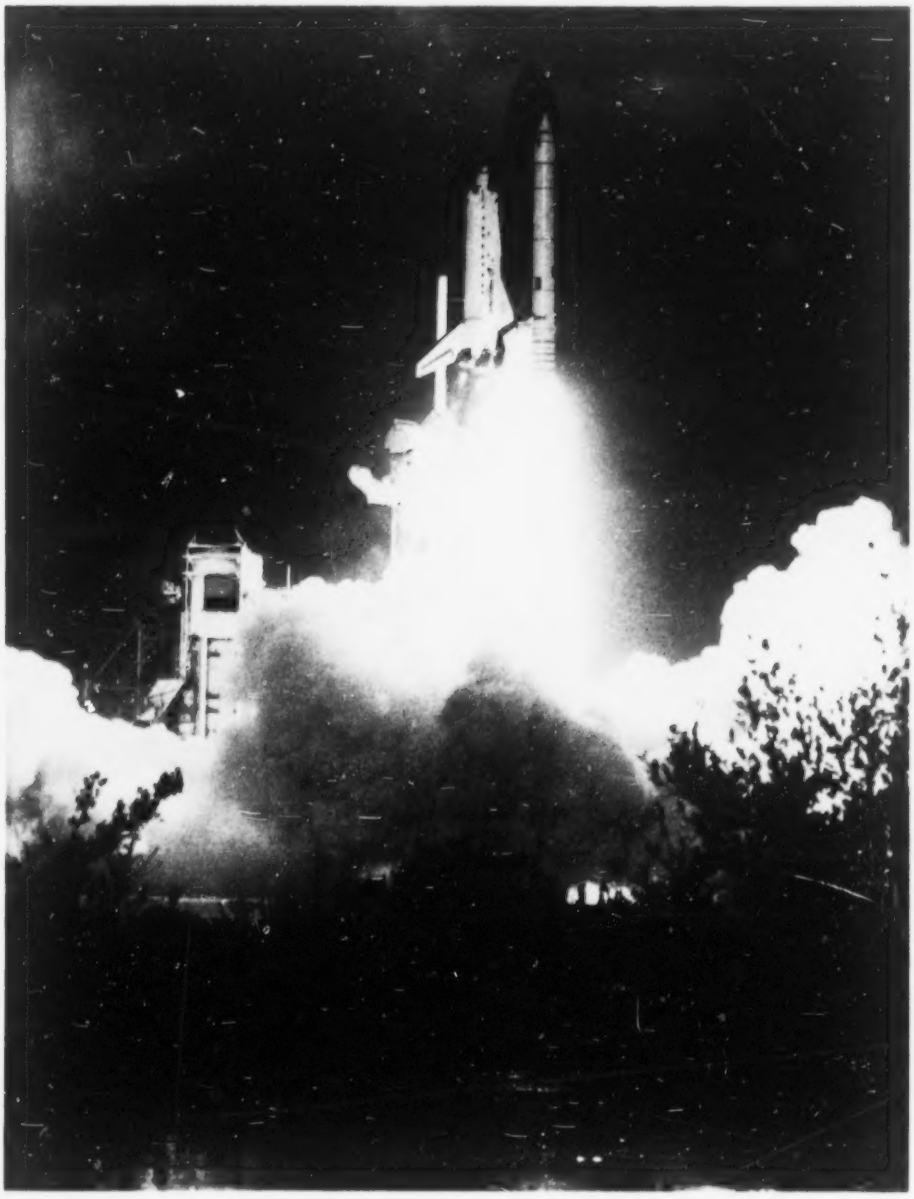
On her right, Comdr. Dale Gardner, who was the lead crewman for the satellite retrieval effort and, as you pointed out, Senator Gorton, with about a seven-month lead time in the success of this Dale was certainly one of the key people in making this happen. He was also responsible for the successful launch of the LEASAT or SYNCOM satellite, which was one of the two satellites we took into orbit.

On his right, Dr. Joe Allen, who was in charge of the launching of the ANIK satellite for TELESAT-CANADA Corporation. He was the other crew member, along with Dale, who was out in the payload bay for the retrieval effort.

With that, what we would like to do is dim the house lights, if we could, and show a few of our slides, which will set the stage for a movie that will follow.

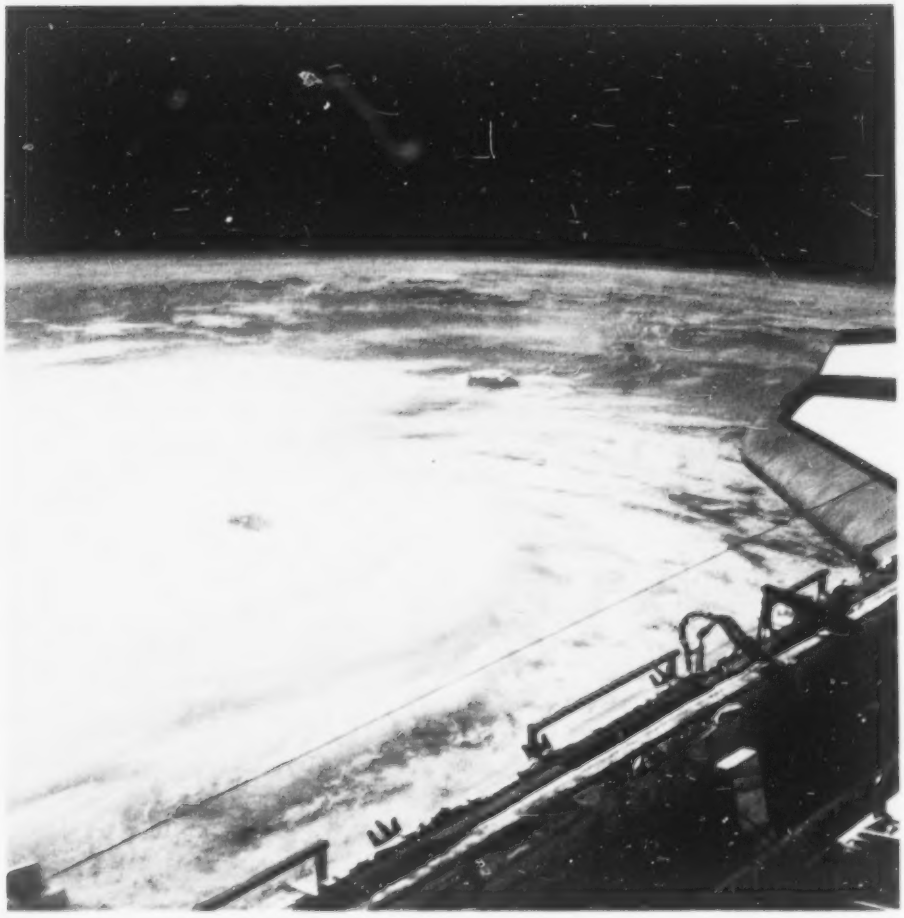
Captain HAUCK. Well, we start with the beginning. To help the transition, here is our launch. As you know, we were one day late in launching due to upper altitude winds that threatened to cause excessive structural loads on the orbiter, so by waiting a day we were able to launch on November 8.

[The slide follows:]



Captain HAUCK. This is a view taken over the starboard wing of the Shuttle in the vicinity of the Mariannas Islands during the mission. It is a picture of Typhoon Bill, which I believe on the next day actually passed over Guam and disrupted the communications capabilities. Actually, some of the remote sites folks had to go to alternate support

[The slide follows:]



Dr. FISHER. This is our first slide to begin discussing how we did the rendezvous and retrieval of the satellites. Our first rendezvous, which was on flight day 5, the rescue of the Palapa satellite, we were in about a 200 nautical mile orbit and Joe Allen was the crew member who was flying the manned maneuvering unit.

He exited the payload bay with what we call the stinger attached to the manned maneuvering unit, and the idea was that he was going to dock with the nozzle end of the satellite with the stinger device, which is being pointed out here, and using his attitude control in the manned maneuvering unit would stop the rotation of the satellite.

This then allowed me to bring the arm out to grapple with a grapple fixture, which is attached to the stinger device on Joe's right side, which you cannot really see here, and thenI would maneuver the arm up and grapple it.

I might mention at this point everything has gone really flawlessly. The orbiter performed well and we were quite excited because everything was maneuvering and proceeding so smoothly.

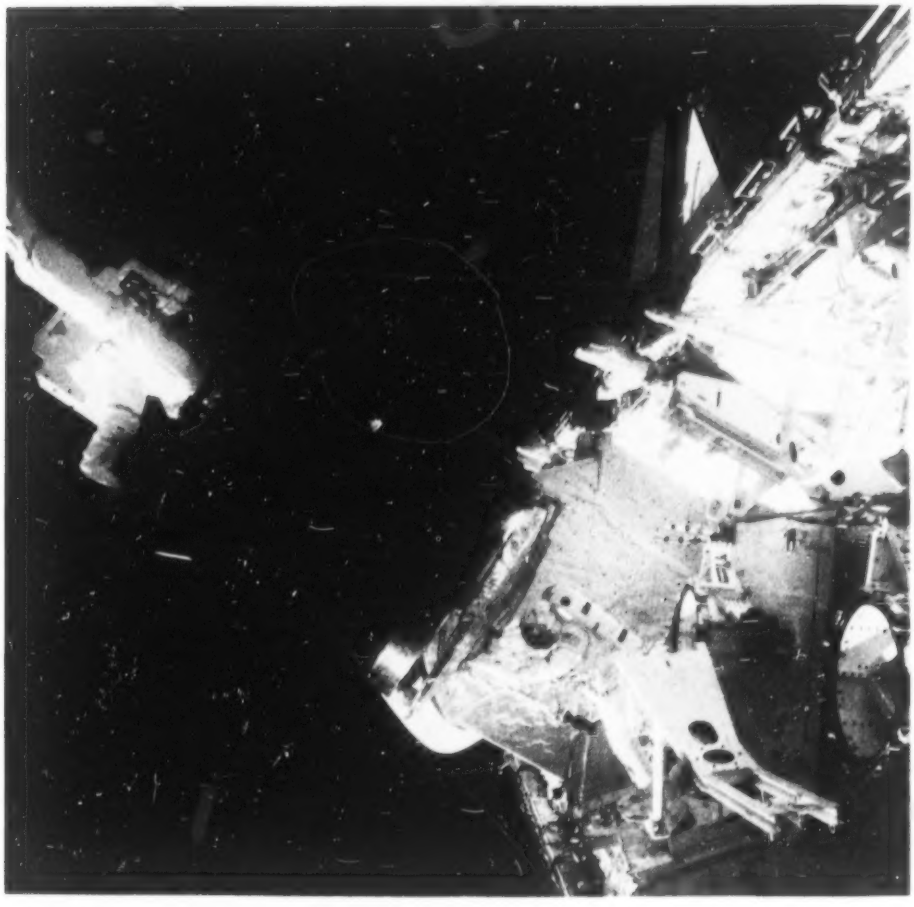
[The slide follows:]

Captain WALKER. This is a picture that shows the mid-portion, really, of the first extra-vehicular activity, and that is Dale Gardner in the payload bay at the bottom of the satellite. He is removing the omnidirectional antenna which was a prerequisite to continuing with the nominal EVA plan which we had developed in flight.

This is about the last place that the nominal time line was actually in operation. The next planned thing to do was to install the A-frame, which is to Dale's left there. Because of an obstruction that was unplanned for and was a result of some documentation problems with the satellite itself, Dale was unable to make that A-frame device fit on the end of the satellite on which he is working.

He then changed horses in mid-stream, as it were, and went to one of the alternate plans that we had developed as a contingency, pre-flight.

[The slide follows:]

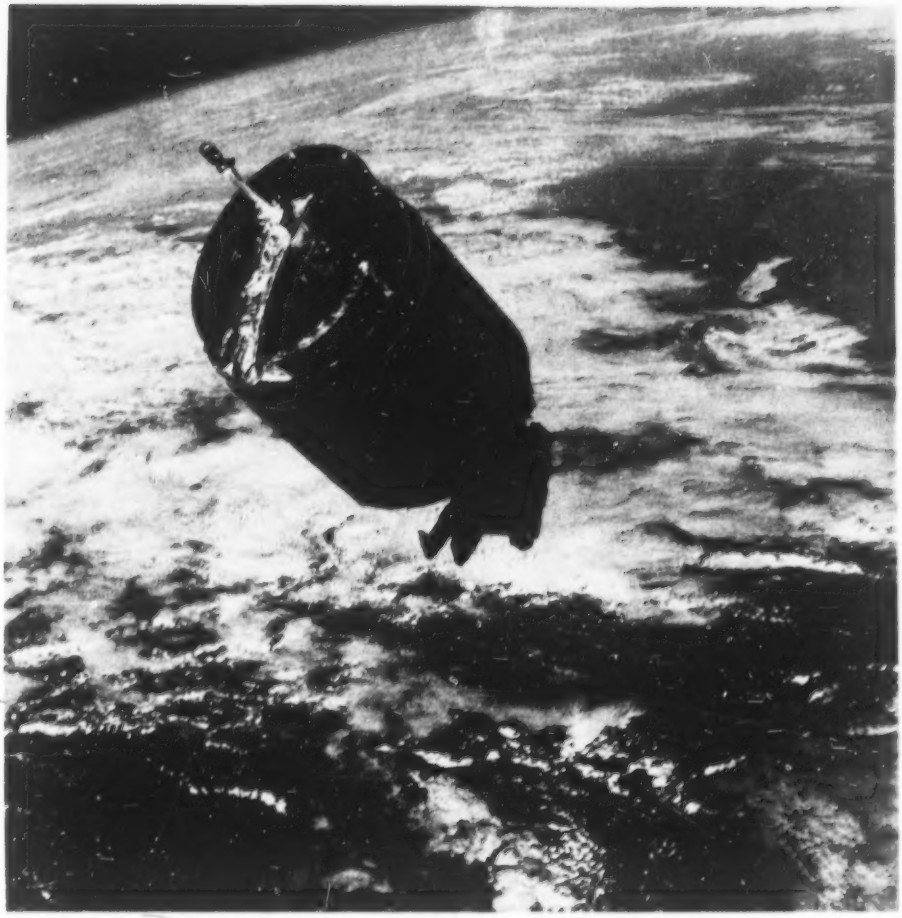


Dr. ALLEN. This was the result of the alternate plan. Instead of the arm holding the satellite attached to the fixture Dave pointed out earlier, called the A-frame, Plan B, as we called it, was for me to hold the satellite.

Dr. ALLEN. We had fortunately taken along a foot restraint for just this contingency and we took the foot restraint out and mounted it on the longeron of the Shuttle and then Anna handed the satellite to me. My assignment was to hold it more or less steady while Dale worked on the other end to remove the stinger, the device we had used to capture the satellite initially, and later attach the most important tooling we had aboard, which was called the adapter. The adapter enabled us to hold the satellite down against the pallet of the Space Shuttle, in fact, in exactly the position you see the adapter in right now.

Captain HAUCK. Joe, while we are looking at that, I might point out that this was, of course, a joint effort by NASA and the Hughes Corporation. Hughes had one of the key tasks, of course, in their flight controllers to bring those satellites down into an orbit that we could retrieve them from.

[The slide follows:]

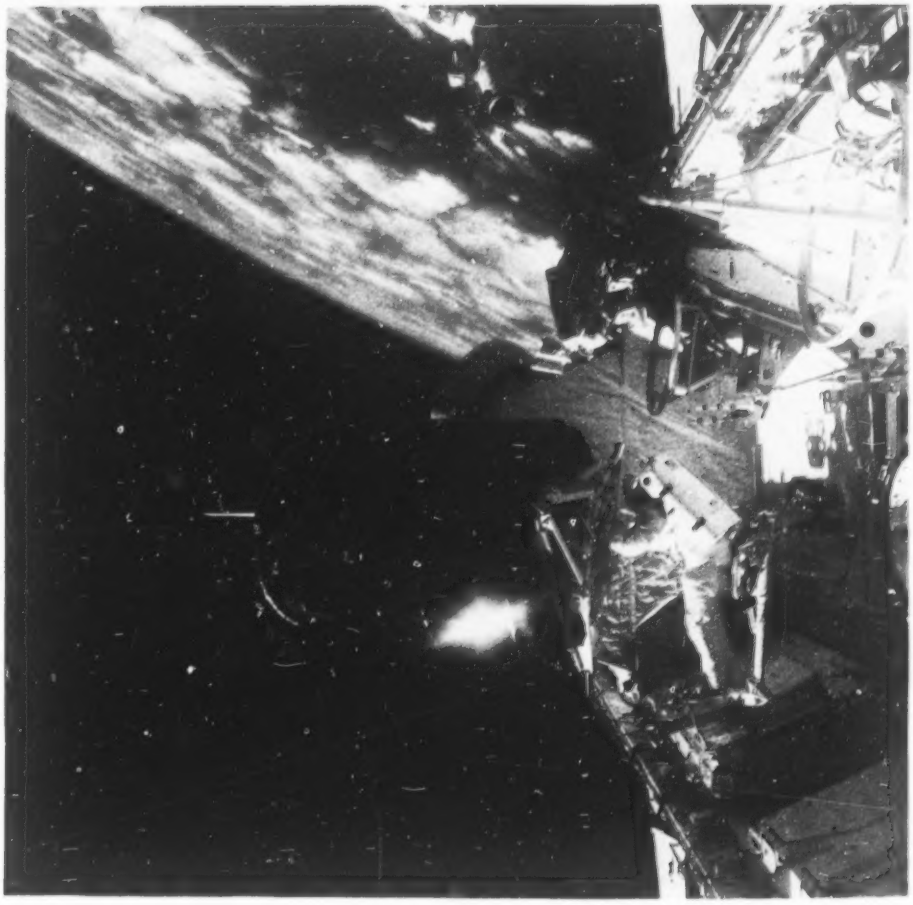


Commander GARDNER. On that last slide, Joe had about 1200 pounds of satellite in his hands. Here I have attached an adapter device to the bottom of it and I am now holding the combination adapter and satellite, which is close to one ton in weight here on the ground, and at this point in the nominal plan, of course, the RMS, the arm, would have been used to berth the satellite, which was one of the jobs it performed so well.

However, since that A-frame did not fit, Joe and I were forced in this situation to manually berth it, and you can see Joe over on the right side getting into position such that I can hand part of the satellite to him and I will grab part of it, and we will just manually pull that one ton down into the latches that would finally hold it into the bay.

This EVA took us about 6 hours, which was about the length of the nominal plan because of its complexity. We were able to change horses in mid-stream plan-wise and still stay within that time frame.

[The slide follows:]



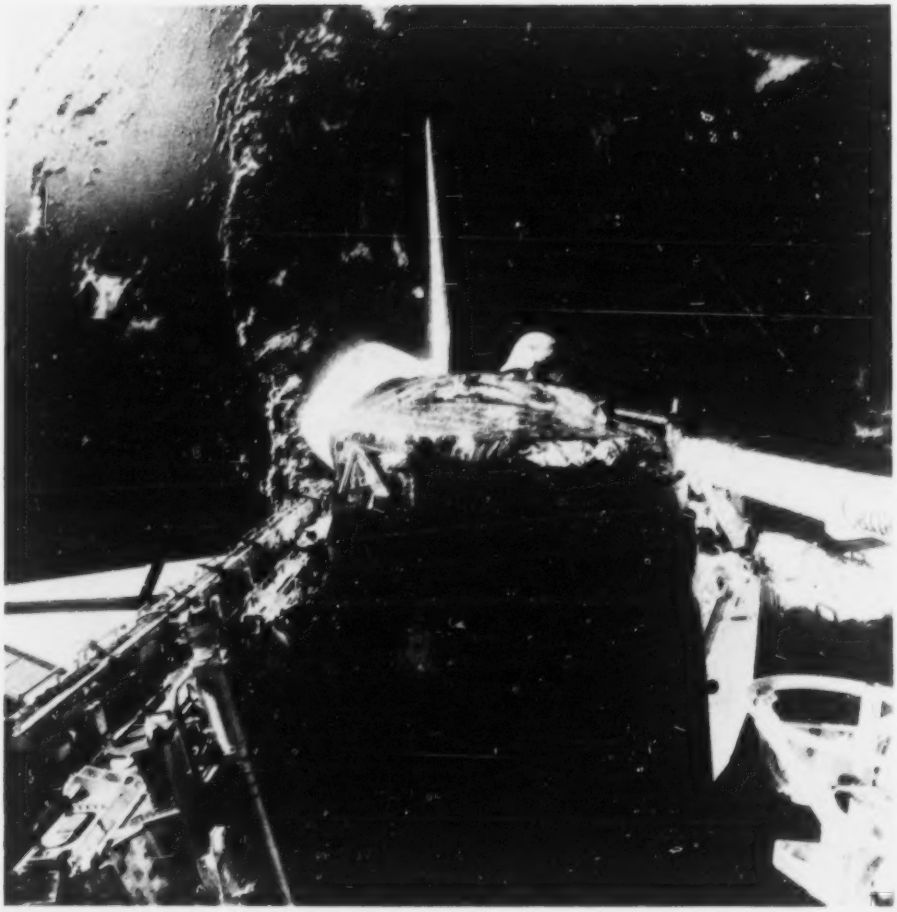
Dr. ALLEN. This is a different satellite. Because of the difficulty we had encountered on the first recovery attempt we changed the plar prior to the second recovery attempt in such a way that we would no use that A-frame just for fear that it would not work on the second satellite also, and in its place, once again, we used me, this time on the arm.

In this particular photograph, Dale has captured Westar. Rick has maneuvered the orbiter close to Dale and Westar, and then Anna has moved me on the arm out to where I can reach out and grasp the satellite. Now about this time I wondered how Dale had talked me into holding the satellite two times in a row, but actually we had planned it that way and it worked very well indeed.

[The slide follows:]

Captain HAUCK. This is our final slide. It shows the two satellites in the payload bay. We would periodically glance out the back window to make sure they were still there. As a matter of fact, after we landed, a flashlight appeared from down on the mid-deck. It was Dale Gardner passing it up to Joe, saying look out the back window to make sure those satellites are still there.

[The slide follows:]



Captain HAUCK. So with that introduction of the slides, we can roll the movie.

[A film was shown, narrated as follows:]

Captain HAUCK. This is our crew patch, which has the symbolism of the two satellites up there, and I will turn it over to Dave Walker to talk about ascent.

Captain WALKER. The ascent was one of the things in the flight that went very smoothly, as planned and as briefed. We trained pretty extensively, as most Shuttle crews do. The main engine fire up is a definite thump but not a big bang, and then the solid rocket motors are a big bang. You see those here. The liftoff is smooth but very powerful. It is kind of like riding an express train going straight up. There is a little vibration but it is a controlled feeling. The roll maneuver is really a beautiful thing to see from inside. From my side particularly you can see the whole coast of Florida.

The first 2 minutes of ascent are on the solid rocket motors, taking us up at around 5,500 feet per second. The solid rockets drop off after 2 minutes and a few seconds, after which the three main engines, which are firing continuously, provide all the thrust, and the solids drop off about 50 miles down-range, about 25 miles up.This whole ride is very exciting for someone who has not flown before, and my eyes were very

Here we have made it to orbit and I will turn it over.

Dr. FISHER. This is the view that greets you once you get on orbit after those 8-1/2 minutes. It is indeed a very spectacular one and one that we were privileged to see.

This is Joe Allen, who orchestrated the deployment of TELESAT on flight day two, while I threw switches in the back for him. This was the ninth Hughes 376, a communications satellite, that we deployed. As you can see, this was a nighttime deployment so our photography was not too great. But that went very flawlessly and we were very pleased with that.

Commander GARDNER. We also deployed, as Rick mentioned earlier, the second in a series of SYNCOM, or LEASAT satellites built and owned by Hughes, leased to the United States Navy. The first was deployed earlier last year. You can see the satellite is quite big. It was made to fit into the Space Shuttle payload bay. It is about 14 feet in diameter and weighs about 13,500 pounds deployed. It comes out in this unique frisbee fashion, as we call it, as opposed to the rapidly-spinning Hughes 376 satellite that you saw in the earlier pictures. Both of these satellites, by the way, are now at geosynchronous orbit and are performing perfectly, according to their owners.

Captain HAUCK. This will introduce you to some of the flight deck activities. Dave and I are performing a flight control systems checkout there and then Dave is going to float down to the mid-deck and you will have a Dave's-eye view as we get down there.

We had a crew of five, but have flown up to seven people on the Shuttle. It has always been a comfortable environment. Of course, in zero gravity all of the extra space, for example, that we have in this room that is not of use to us in one G would be of use to us in zero G.

Our lockers on the far side is where we stow all the crew equipment. In the lower righthand corner, you could just see the handles for our treadmill, where we get our exercise on orbit for our legs. On the far side are two blue sleeper restraints. You can sleep up against the side of the wall or sleep on the ceiling, if you want to.

This is Dale and Dave taking some panels off to clean some filters on some of the electronic equipment. It is indicative of the daily housecleaning that we go through. We clean filters probably once every three days. Being a Naval officer and three of us from the Navy on the mission, we know that a clean ship is a happy ship, so we worked very hard to keep this vehicle clean.

Anna here has a portable vacuum cleaner. She is reaching up into one of the crevices where some of the electronic filters were located.

Anna, why don't you talk about this?

Dr. FISHER. Meal prep was something that I always looked forward to. It usually took two of us, and we took turns doing that. The food is very similar to backpacking food, and is either thermally stabilized meat or rehydratable. Here you see it stowed in our lockers. It is arranged according to breakfast, lunch and dinner. It took about a half hour for us to prepare a meal. You can see the water dispenser in the back there.

The thing I always looked forward to, however, was dessert. Of course, in zero G you get unique ways of being able to eat. Rick also used this as a means of rewarding usif we did a good job. I guess he thought I had done a good job on that meal.

Captain HAUCK. The motivational aspects of a flight are very important.

Commander GARDNER. This is the start of the EVA activities. The airlock contains three suits. We have two prime suits and a backup, as you can see underneath my right leg there. Fortunately, the suits worked perfectly and we did not have to go to the backup or third suit.

Dr. FISHER. While Dale and Joe and Dave were working on the mid-deck getting their suits ready, Rick and I were up on the flight deck performing a series of burns that would be required to bring us into proximity with the satellites. There were over 24 burns which were executed flawlessly, both with computations from our computers on board and with help from the ground.

This is a view of the Westar satellite through our optical sighting device through the overhead windows. You can see the satellite here in the lower lefthand part of the vertical. This isat about 50 nautical miles. I cannot tell you how happy we were on board when we saw that.

This is the view that we had looking through the overhead windows. At this point Rick is flying the orbiter manually and bringing us in proximity with the satellite. Actually, he is braking because we are essentially on a collision course and he is doing the braking to put us in a stable position.

Dr. ALLEN. This shows a view as seen through the back windows of the orbiter of Dale and myself outside getting ready to go after Palapa. In this instance, I am flying the maneuvering unit. That is a view that an outside TV camera had of Palapa. You can see that Rick had nestled the orbiter right up close to the satellite. And with words of encouragement from on-board, off we go. The flyover process with the maneuvering unit is very slow appearing, and in fact it seems to be in slow motion when you actually fly it. We moved very deliberately to conserve the amount of propellant we had for the MMU. We moved over very slowly to the satellite. In this case it is Dale flying over past the arm.

It is not unlike, for those of you who fly airplanes, flying on downwind and then pretty soon you will turn onto a final. As he lines himself up with the aft end of Westar, in this case, you will see that Dale is using the shadow of the orbiter itself to keep the sun out of his eyes as he comes up on Westar. The sun is almost aligned with the antenna of Westar, so it otherwise would be right in his eyes.

It proved to be a rather easy matter to fly out and dock with the satellite, as Dale has done here. You see he is spinning, but in a few moments he will engage attitude gyros and stop the spinning of both himself and the satellite, and then Anna will come over with the arm and affix the two of them to do later work on the satellite.

Commander GARDNER. Of course, inside Rick, as Dave mentioned, was the orchestrator and he read Joe and I all the procedures because it was a very complicated task to do the whole EVA.

Dr. FISHER. This is the view I had looking through a camera at the end of the arm as I was going in to grapple. You can see a trunion sticking out from the grapple fixture. And this is the view from the outside eye as I was getting ready to move the arm in to the grapple. That went as we had planned.

Captain WALKER. Inside the spacecraft, the three of us continued to support the folks outside as best we could. Here is one of the things that we did. All the documentation, the photography that you see from inside the spacecraft looking out was done generally by Rick and Anna and very occasionally by me as the two outside crewmen continued to work, as well as manning the orbiter systems and working the communications between the people outside, the people on the ground, and those of us inside the cockpit.

This is, incidentally, the common bracket clamp that Dale was trying at this point to attach to the A-frame or to the satellite itself so that the A-frame would fit on it. We were somewhat concerned at this point when it did not work; but we quickly replanned.

Dr. ALLEN. Well, Dale and I talked it over and waited until we talked to the ground, and stated that we thought we should go on with Plan B, hoping that Dave did indeed have a Plan B there in the cockpit—and he did. The plan was for me to come down off the satellite, put away the maneuvering unit so we would have it out of the way and then once again I would be used to hold the satellite while Dale worked on it.

You get some idea of how smooth and easy it is to fly a maneuvering unit like this. You can see me move my hands very, very slightly in order to control it. This is a interesting movie footage, in that you can see the front end of the orbiter reflected in my helmet. You see the two windows that the crew inside is looking out through. In fact, you can almost see the movie camera that is taking the movie right there—all reflected in the visor of the space suit's helmet.

On the top of the helmet you see on either side two things that look like miner's lanterns, and indeed that is exactly what they are. It is daylight for 45 minutes and then it is darkness for 45 minutes as you orbit the Earth, and so we leave those lights on all the time. When the sun sets, we then use those lights to find our way around in the working volume of the payload bay.

Commander GARDNER. Well, here Joe has held the satellite for me while I removed that stinger device which he had left on the rear of the satellite. Then I asked Joe to move the satellite up out of the way so I could put the stinger away and mount it in the payload bay. You can see Joe very easily is raising that 1,200 pounds up over his head, Atlas fashion. Joe held the satellite, by the way, for 90 minutes, one complete revolution around the Earth, on this first space walk.

You can see over here we each have tethers on us that attach us to the payload bay so that in case we should let go and become loose, Rick would not have to fly the orbiter over to pick us up.

Finally, of course, Joe held it while I attached this adapter device, which is going to be the interface between the satellite, which was not meant to be recovered, and the payload bay of the orbiter. It had nine latches on it that I used a fairly common torque wrench on, with a 6,000-pound load on each of those nine latches. That was to ensure that during the reentry process, of course, the satellite would not come loose.

And here, as we saw on the slide, the adapter is attached. I am now aligning that adapter with its latches in the payload bay and in a minute Joe will join me and we will try to manually put the satellite into the bay.

Captain WALKER. Inside the spacecraft the three of us, who had been subsisting on peanuts, M&Ms, and an occasional lemonade, were ready for these guys to get finished. As you can see, the successful outcome of it made it all worthwhile.

Captain HAUCK. Well, we understand that there was a certain amount of rejoicing back on the ground at this point, but it is not over until it is over, and that is us passing over Houston at Mach 18, at 190,000 feet, leaving a trail of electroluminescence.

The weather was good enough for us to come back into the Cape Kennedy Space Center. Of course, it is desirable to get back there because it minimizes the turnaround time on the Shuttles, saves about 5 days that would otherwise be spent flying the Shuttle back from Edwards Air Force Base. The approach speed was about 285 knots, close to 300 miles an hour, flaring at about 2,000 feet. Dave put the landing gear down at 200 feet. This was just prior to sunrise on the 16th of November.

I guess we could turn it off now and make some concluding remarks.

If we could, we would like to summarize in about 2 minutes each what we feel the significant aspects of this mission, and their impact for NASA, and for its capability in the future. I will start by saying that our sensors that we used to rendezvous with, star-trackers and rendezvous radars, all worked flawlessly and the rendezvous, although very complicated, worked out very well.

As I mentioned before, having those satellites positioned on orbit in a stable condition, as Hughes left them, was very important to us.

Dave.

Captain WALKER. The orbiter systems which we are required to have, obviously, just to survive as well as to do the mission itself all worked very, very well. This was critical because we were very busy. Had we had to divert our attention to an extensive orbiter problem we would have had a difficult time doing the task. I might also mention with the proximity operations, that portion of the orbiter-to-satellite maneuvering that occurs right at the end, worked extremely well. It was a slight change, and perhaps some small improvements in technique, and it worked out so that we were able to get close to the two satellites, without disturbing them by our presence, with our reaction control system jets.

Dr. FISHER. I would just like to mention once more the diffuse mixing of organic solutions, the experiment which we flew for the 3M Corporation. That was conceived fairly late in the game. I think they started working in February on it and they again had a fairly short lead time, as with the other hardware we carried. Their experiment performed very well. They were able to grow crystals by the process of diffusion larger than they had grown in their ground-based experiments. Hughes is very pleased with the results and is looking forward to additional flights and future applications.

I would also like to mention that the RMS, or remote manipulator system, which was built by Canada, performed beautifully on this flight, and we were able to do something slightly different on this flight. The idea of maneuvering that satellite with a flexible grapple fixture, if I can refer to Dr. Allen in that fashion, worked very well.

Dr. FISHER. It is not something we had been able to practice on the ground because we do not have any simulators that can simulate that aspect, but because of our training we were able to do that and it worked very well.

Commander GARDNER. Well, concerning the space walks, I would like to mention two different areas. One is the work load on the crew and then the second area being handling the objects manually.

You noticed we had five people and in the movie you could see all of us working—two out in the bay and three in the cockpit. It turned out that for this complicated rendezvous operations and space walk that five was really the minimum number we could have operated with.

Senator GORTON. You do not believe that you would have succeeded had you only had four?

Commander GARDNER. It would have been very difficult. In fact, we would not be here today with all of these nice movies and pictures because we certainly would not have the time to do that. Let me explain what we were all doing at one time. Joe and I, of course, were out in the bay. Rick and Anna had the responsibility for the proximity ops and the rendezvous and controlling the satellite. And Dave was our valet, if you will, during the suit-up portion and the unsuiting and also was the person in the cockpit that had the overall plan, if you will, for the total EVA.

As a matter of fact, when Joe and I came back into the cabin after each of the EVA's, we were somewhat tired, of course, but feeling pretty good about the success, and when the airlock opened we expected to see three very excited people inside. Indeed, that was not the case. Rick, Anna and Dave were, in our opinions—Joe's and my opinion—much more tired than we were from the mental exhaustion of having to take care of the mission in total.

All Joe and I had to do was go about each task at a time. The three people inside were communicating with the ground, running the orbiter, keeping track of us, handling the documentation, working up other plans. It was really a long day for them. So we felt very lucky that we had the coordinated effort that we did to pull off the spacewalk.

Concerning the handling of large objects, in a way we feel a little bit fortunate in that with the failure of the A-frame to fit on the satellite, of course we would have liked to have the plan go nominally—I mean, that is the way we intended it—but we probably learned things here that we would not have learned, most assuredly, had the A-frame fit, in that never before had men in space in spacesuits handled objects of this size or mass. We found that particular task to be quite easy, with a couple of caveats, one being that when you are holding a satellite that size, and as you saw Joe doing it, you could see that his face was really full of satellite and he could not see what he was doing with it.

It takes other people, in fact, the people in the cabin, to tell you where the satellite is and where it is moving. You do not have a good sense for the very small motions that can take place. So if it is going to be something large, you really need to have somebody there to help you out.

The other thing, of course, was that while we are holding these large objects we have our feet firmly attached to the orbiter itself in that foot restraint that Joe mentioned. If you tried to be floating free, hanging on with one hand, as you can imagine, every time you tried with one hand

to put a small force on that object that force would react back through you, causing you to move also, making it a quite difficult situation. So by having your feet attached to the orbiter, making you part of the orbiter, if you will, it allows you then to apply those forces—which are very small, by the way—to produce the small motions. So we feel fortunate that we were able to experience that and hope that we will be able to advise those planning on building structures in space in that regard.

Dr. ALLEN. Mr. Chairman, in conclusion I would like to come back to something that you began with in your introduction, and that is just underscoring the fact that only about 2 years ago, a little over 2 years ago, some of us were here with you testifying on the fact that the orbiter had become operational. We had taken satellites to orbit using the National Space Transportation System.

This was a little over 2 years ago. It is even more difficult to realize that the satellites that we described today in terms of recovery were lost not a year ago. They were lost in February of 1984, and in the few months between then and now a team that involved NASA, involved NASA contractors, and involved in fact the business people around the world that had an interest in the recovery of these satellites, this team worked on the problem, came up with the technical method to recover the satellites, trained the astronauts.

And the Space Transportation System was, in fact, flexible enough to carry out this seemingly complicated mission in a shorter time than the 12 months. So we think, with you, it is a most remarkable accomplishment. We are pleased to have been a part of that team and very pleased at the opportunity to testify before you on the mission today.

Senator GORTON. Thank you, Dr. Allen. Thanks to all five of you.

Dr. Allen's last comments, Captain Hauck, really leads to my first question of you. You did have only a relatively short period of time to prepare for this task. You obviously used that time extremely well. How close did the difficulties which you anticipated during your preparation finally correspond with the difficulties you actually found there?

Did you spend a whole lot of time preparing for the difficulties or problems that did not exist, that did not take place?

Captain HAUCK. That is true, Mr. Chairman. By the very nature of the system, of course, we spent a lot of time training on difficulties that could be injected just on launch or reentry.

Specifically as they relate to the retrieval mission, though, we spent, I would guess it was, towards the latter part of the last 30 to 45 days prior to our launch looking at failure modes such as the one we had, really sketching them out in bullet format. Joe and Dale did not have the opportunity to go into our water tank to practice how to cope with these, but we did have other astronauts who did. We were busy enough in our training in the latter stages that they did not have that luxury. We predicted that we would have some failures. This thing just came together in a short enough amount of time and there was enough mechanical interface that you know something probably will not work, and we did look at each of those mechanical elements—what if this were to fail—and had methods to cope with that. The one that we could not have coped with is if that adapter had failed. That was paramount that that be able to set the satellites in the bay.

Senator GORTON. Dr. Allen, was the April Solar Max repair mission and the lessons which came from that absolutely vital to your success in this mission?

Dr. ALLEN. Yes, sir. I think there is no question about that. In fact, each NASA mission has in many ways followed in the footsteps of the ones just before, and this is certainly no exception to that. We learned from each of the space walks that have been done by our colleagues, not only during Shuttle missions but even during the Skylab times and Apollo before that.

We, first of all, talked to the people that had been there. We kind of learned from them. We also would look at TV of their working outside in zero gravity and pretty much used the knowledge that they had put back into the system via improved simulators and so on to enable us to not start from ground zero, if you will, but start from a fairly high level of experience. And, we are hopeful that missions that follow ours will be able to do exactly the same. We are confident that these missions will.

Senator GORTON. Commander Gardner, even so I gather that these two retrievals were more difficult because, unlike Solar Max, these instruments were not designed for retrieval, I gather. What additional difficulties did that raise? I guess we sort of start with the fact that—well, the fact that your one initial failure you had to do it in the first fashion had to lead you on to a second, Plan B.

Commander GARDNER. Well, that is exactly right. The spacewalks, as originally envisioned, were very complex because of the fact that the satellites were never intended to be recovered. That caused us problems in a couple of regards, the first being that with satellites that are built one-of-a-kind, such as these are, built specifically for the customers, the Indonesians and Western Union in this case, the documentation on those satellites could not be as accurate as you would expect for something that was mass produced. And, you can see what happened. We ended up having difficulty attaching one of our pieces of hardware because of interference.

The aspect about the satellites that really made the task difficult, of course, was that, as you might imagine, satellites are very fragile structures and their weight is being kept to a minimum as a prerequisite; therefore, the structure of the satellite is very flimsy. There just were not a lot of places on the satellite for us to design hardware to grasp it. As a matter of fact, you could see that the end that we grabbed it with the stinger was also the end where we eventually wanted to be able to put that adapter on to put it in the bay. That is what made the EVA complex. You had to grab one end, build a structure on the other end, transfer the arm from the first to the second, remove the structure on the first end and then put the adapter on. That is what took what originally looked to be a simple task and made it very complex.

Senator GORTON. Dr. Allen, under the circumstances as far as the future is concerned, is Plan B better than Plan A?

Dr. ALLEN. Well, that is a very good question. We are considerably smarter now, more experienced than we were prior to going up to retrieve the two satellites. You are asking, I think, if we set out to retrieve two more would we do it in exactly the same way.

I am sure that the answer is "no". We would do it more easily. We could do it more rapidly and in a way that would appear less busy but would be equally dependable. We could mention some specifics but I think that gives you the general idea of what you are asking.

Senator GORTON. Dr. Fisher, you had to change plans too in connection with operating the RMS. What kind of problems or concerns did the change in methods present you with?

Dr. FISHER. Well, although I had not been able to specifically train for, on the second rendezvous, maneuvering Joe up to grab the satellite manually—he was going to be in foot restraints and move around, we had practiced that kind of communication, but not that specific task. So I think we were well coordinated.

Again having talked about that on the ground I think we were prepared to do that. Since the arm performed as well as it did, it was not particularly difficult. Had the arm had a problem with some of its computer-supported modes and had to operate in one of the less capable modes, then it would have been a lot more difficult and we had not trained on that. But I felt very well prepared, again because the hardware performed flawlessly and because we had at least spent time on the ground talking about that kind of voice communication.

Senator GORTON. And the arm is Canada's contribution to the mission and the Shuttle?

Dr. FISHER. Yes, that is correct.

Senator GORTON. Mr. Walker, is it Captain now?

Captain WALKER. Yes, sir, as of the flight.

Senator GORTON. Congratulations. The biography is old; you have been promoted.

Captain WALKER. Well, it is a very recent promotion, so the biography is not too far out of date.

Senator GORTON. During the Solar Max repair maneuvers the Shuttle maintained a distance of about 200 feet from Solar Max. You brought it considerably closer than that. Were there any particular risks closing in to that distance?

Captain WALKER. The main thing that had to be considered, Mr. Chairman, which Rick and I, as well as a number of the engineers and developers of these procedures at Johnson Space Center, worked with was whether we could approach that close without disturbing the satellite itself with the reaction control system which controls the orbiter's translation and attitude. And through simulation, both mathematical and crew-in-the-loop type simulation, it was determined that we could do that. Once we had practiced it in our simulators, it appeared to be the more desirable way to do it. The problems were that we had to be very, very careful not to allow the plume from the reaction control system of the orbiter to hit the satellite, and by changing our techniques a little bit we were able to do that.

Senator GORTON. Dr. Allen, how serious or how exhausting were the physical demands of handling those two satellites, holding them motionless for 70 or 80 minutes during each of the maneuvers?

Dr. ALLEN. I think it is fair to say that it was considerably easier than it may have appeared to those of you on the ground. By that I mean the satellite looks very large and awkward. It, however, weighs nothing. It is just a matter of babysitting it or tending it, not holding it up. This is true even though your hands may be over your head. You are not holding your hands or your arms up in doing that.

The assignment to work outside a spacecraft in a space suit for many hours, however, is not totally a bed of roses. In that the suit is bulky, you feel quite cumbersome. It is not easy to move yourself along with great control, and to do that takes considerable practice on the ground, and then it takes a certain deliberate approach to it in the zero gravity of space.

Dale and I worked for about 8 hours time. At the end of that time we were pleased that the task was completed and it was time to come in. I might say that much of the demand is mental and not all physical.

Captain HAUCK. If I could interject, Senator, I might mention that both Dale Joe, and every EVA crewman goes through an even more rigorous self-imposed physical training regime and building up upper body strength is very important. So easy is maybe a question of relativity.

Senator GORTON. Captain Hauck, this is a question which really does not relate to the technical success of the mission, but we do see and are concerned about the fact that even after the success the insurance rates to the private sector in sending up satellites are very high and represent a major cost of those missions.

I simply would have the question as to why was or is the recovered value of those two satellites so much less than their insured value? Why does getting them back and being able to sell them again only bring back a modest portion of what it cost in the first place? Do you know?

Captain HAUCK. Well, of course I am not an expert in that field, but my understanding is that, for example, a $100 million insurance policy on a satellite not only insures the hardware. It also insures the launch costs and insures a certain amount of the revenue that is expected to be gained by those satellites being in orbit. So the hardware is really, even to begin with, a fraction, and I cannot tell you what the fraction is, of the cost, and, as such, when the hardware comes back a certain amount of effort goes into refurbishing and really what you are getting back is the hardware. The future customer has to pay again for the launch and has to wait until the satellite is a revenue-producing object.

Senator GORTON. Thank you.

Senator Danforth?

The CHAIRMAN. Is this a stressful thing to do, going up in space and being shot up in a rocket and orbiting for 8 days, going out and tending to satellites that are missing, then coming back down on a little landing strip somewhere that is relatively small considering the size of the universe? Is this stressful, or is this something that just anybody could do without batting an eye?

Captain HAUCK. I think by the time we get to it, Senator Danforth, certainly while we are sitting on the launch pad—and I will speak for myself, obviously—my thoughts were not filled with fear of failure. I think we have trained to a great extent and had great confidence obviously in the hardware that we have and the people that are supporting us.

Those of us that are pilots and co-pilots of the Shuttle have come through the world of test piloting, of course, and have been exposed to what you might consider to be greater dangers in that world than perhaps in the Shuttle program.

I think that we have to recognize, though, that it still is a risky business. We have launched the Shuttle 14 times. It is not a guaranteed success. I think that is in the back of our minds.

We spend 30 percent of our training time, even these days, training for failures that can happen on the launch and ascent portions of the mission. That is an indication of where we recognize the greatest hazards to be. So I cannot say that we sit back and worry ourselves about what we are doing. We are obviously dedicated to it and I think you will find the folks that apply for astronaut jobs are adventurous people, and they are probably the same kind of people that enjoy going down ski slopes or trailing behind a water ski boat. I think you find a certain mentality there that is important. As far as the actual labor on orbit, I have to admit—and maybe it was because, again speaking for myself, being the Commander of the mission, that I found it to be very stressful.

The CHAIRMAN. I am sorry?

Captain HAUCK. I found it to be very stressful, perhaps being the Commander of the mission.

The CHAIRMAN. Being Commander was stressful?

Captain HAUCK. I think it was. I had the worst headache that I have ever had after we got Dale and Joe back into the cabin. And I recognize, I think, in retrospect that I was concerned. I did not let it bother me during the flight; but it was the worst headache I ever had and there was no question it was caused by stress.

The CHAIRMAN. Well, how about the rest of you? Did you feel relaxed? Or, let me put it this way. When 8 days were over, were you ready to come back down or could you have willingly stayed up?

Commander GARDNER. I think we were all ready at the end of 8 days. It had been 8 very busy days for us and somewhat stressful, as Rick mentioned. Interestingly enough, in preflight we were so busy worrying about technical aspects of this that I do not think any of us felt any pressure from the other communities that were involved, and particularly the legal and financial communities, until about that last week prior to launch.

We went into quarantine and we happened to see on the Public Broadcasting System, a 30-minute special made by BBC because of the Lloyds of London connection with the insurers. We suddenly saw that these people were putting down $10.5 million, these people that we had never seen and obviously had never seen us, risking $10.5 million— on this mission and counting on us and the rest of the NASA people to pull it off. That was the first time that I frankly felt any tinges of anxiety at all. To that point, it had just been a job to do, but then we saw the big picture and that really rounded the whole thing off for us, right before launch.

The CHAIRMAN. I am not asking, you know, just whether you were scared. I would be. I am the kind of person who when my kids want me to go up in a Ferris Wheel I say no, please do not make me do that. But there are other things that normal people, I would think, would have a hard time coping with, for example, being in a relatively small area for a prolonged period of time, or weightlessness.

When you showed the pictures of the sleeping bags, I cannot imagine sleeping unless I feel, you know, something under me. Did you sleep well?

Dr. FISHER. Since I was the one that seemed to have slept best onorbit, let me answer that one. There is a period of adaptation to zero G. Certainly, you know, speaking for myself, for my first time in space for about the first 2 days you feel very clumsy, very awkward, and it seems like a very foreign environment, which it is—learning how to operate in zero G, how to sleep in zero G, how to brush your teeth—all those simple things that you take for granted. Everything requires a thought process. I would say that about after the 3rd day, certainly by the 4th day, suddenly that environment becomes very comfortable. It suddenly becomes as though you have been there really all your life. In terms of sleep, I think that is very individual. The first night I do not think anyone sleeps very well because again you are adapting to a new environment. And after that I know my fellow crew members had to wake me up because I missed all our wake-up calls after that first night. So again that is all so very individual. But, certainly the first day or two requires adaptation, but then I think you get used to it and it is a very pleasant environment.

Talking about the confinement, as Rick mentioned, in zero G you have the entire volume available to you. You are not just limited to being on the floor, and once you have adapted to zero G and can get into any orientation and it does not bother you, you really have more volume than might be apparent if you looked in one of the mock-ups in a 1 G environment. It is really very much like a camping trip in terms of habitability, in living space, but it is very comfortable.

To answer your question, I think at the end of 8 days, though, you feel like you do at the end of something you really enjoyed, a vacation, but you are also looking forward to going home.

The CHAIRMAN. Well, in the space station it is my understanding we intend to keep people in it for a half a year. Is that unimaginable, do you think? Or would that be something that would go well? Is that unrealistic?

Dr. FISHER. Maybe I can take a stab at that. Again you would have to take that into account in your design requirements. The Shuttle was never designed for missions longer than probably a maximum of 2 weeks. If you start out with a space station and design it for longer durations, I am sure that zero gravity could be a place where you could stay for extended periods.

Obviously, the Soviet Union has demonstrated they can stay out there for quite a long time, so I do not think we will have any problem with long durations. We just need to take that into account in your design.

The CHAIRMAN. Would you want to do that?

Dr. FISHER. Definitely.

The CHAIRMAN. Would the rest of you all want to go up, or is this the kind of thing you do once?

Captain WALKER. Again speaking just for myself, but I feel pretty confident that the others would say something similar, we are in this business and have devoted a tremendous amount of time, effort, and a significant portion of our lives to it. We are here to fly and we would go as often and stay as long as we could.

The CHAIRMAN. What advice do you have for us? This Committee has the responsibility for authorizing the NASA program and overseeing it. Obviously everybody in government now is concerned about the budget. What advice do you have for the Congress?

Captain HAUCK. We had an opportunity, Senator, to go throughout the United States on a monthly basis to talk to people and, as per the charter of NASA, to talk about what we are doing. In 7 years of my going out and talking to people of all walks of life, whether it be kindergarten children or folks in the Rotary Clubs throughout the country, I have never ever had one negative comment made about our nation's space program. To me that indicates a tremendous grass roots support for it. It is a rallying cry, it seems to me, for the country. I think I saw in the paper recently a UPI article that summarized the 10 most significant news stories of 1984. Nine of them were negative—scandals, disasters, whatever; one of them was our mission. I think that is indicative of what NASA can do as far as the spirit of the country. I think it is very important. That is certainly one aspect.

The technological base that I think we represent is very important. I would hope that with all our national priorities—and I know that our budget is one that we have to look very closely at—that I would recommend, since you have asked for my recommendation, that we give as much as we can, within the priorities and within other constraints that we have, to a program that provides us with an uplifting of our national spirit, I think, as well as contributions to our technical base.

The CHAIRMAN. Do you think Senator Gorton should make a reservation to go up in space?

Captain HAUCK. Do you like to ski, Senator Gorton?

Senator GORTON. Yes.

Captain HAUCK. I think you would enjoy it.

Senator GORTON. Are you going to be able to use Senator Garn effectively and get him back here in time to vote on your budget?

Captain HAUCK. Well, if I were the Commander of that mission, I sure would.

Senator GORTON. Senator Cannon, would you like to ask some questions?

Mr. CANNON: No, thank you.

Senator GORTON. Dr. Fisher, one other question on the past and future of this retrieval. Based on your experiences so far, do you think that we can retrieve successfully Landsat IV?

Dr. FISHER. I really have not been following that as closely as perhaps I should, but it is my understanding that Landsat is in a polar orbit and so that would, of course, necessitate a launch from Vandenberg. But based on everything that I have seen, I do not see why we should not be technically able to do that, once we have Vandenberg available as a launch platform.

Senator GORTON. Are there circumstances under which we could retrieve, repair in space, and relaunch satellites without bringing them back to Earth?

Dr. FISHER. Well, Solar Max is a good example of one where we did that. I guess that is going to depend very much on the nature of the satellite that is up there and whether you can actually repair it. Yes, I think that is possible and we have demonstrated it.

In the case, for instance, of these satellites they required refurbishment that was very much more extensive than what we could have done on orbit. The resale of them would probably require some changing of the antennas to fine tune it for the new owners. So I think it just depends very much on the satellite and its mission.

Senator GORTON. Well, in the case of these satellites, was it because they were so badly in the wrong orbit or was there something mechanical for which they had to be brought back to Earth to repair?

Dr. FISHER. The solar panels needed to be refurbished. They needed to get additional fuel. We had spent the upper stage booster, which was needed to put it in a geosynchronous orbit. We used it to bring it down to our altitude. So there were quite a few things that neededto be done on those satellites. Although their functioning parts in terms of the communication satellite aspect were adequate, some of the consumables needed to be replaced, for one.

Captain HAUCK. If I may, Senator, we were really very fortunate that the failure occurred as it did and left those satellites in the orbits that they did. It is almost beyond belief that two could fail in the same manner and leave them in a position that they could be retrieved. Had those motors that malfunctioned fired maybe 10 seconds longer prior to malfunctioning, they may have been out of an orbit that we could have gotten them from.

Senator GORTON. Senator Danforth?

The CHAIRMAN. No more questions.

Senator GORTON. Thank you all very, very much. Captain Hauck, thank you for telling us about the reception you received around the country. I think you have put your finger on the pride that the people in the United States have in NASA and in you all as individuals and what you are doing to add to the knowledge we have about the world and about the space around us. We greatly appreciate your contributions.

Thank you all very much and the meeting is adjourned.

Captain HAUCK. Thank you.

[Whereupon, at 11:10 o'clock a.m., the subcommittee adjourned, to reconvene upon the call of the Chair.]

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